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(54) SYSTEMS AND METHODS FOR FIELD DEVICE FEEDBACK

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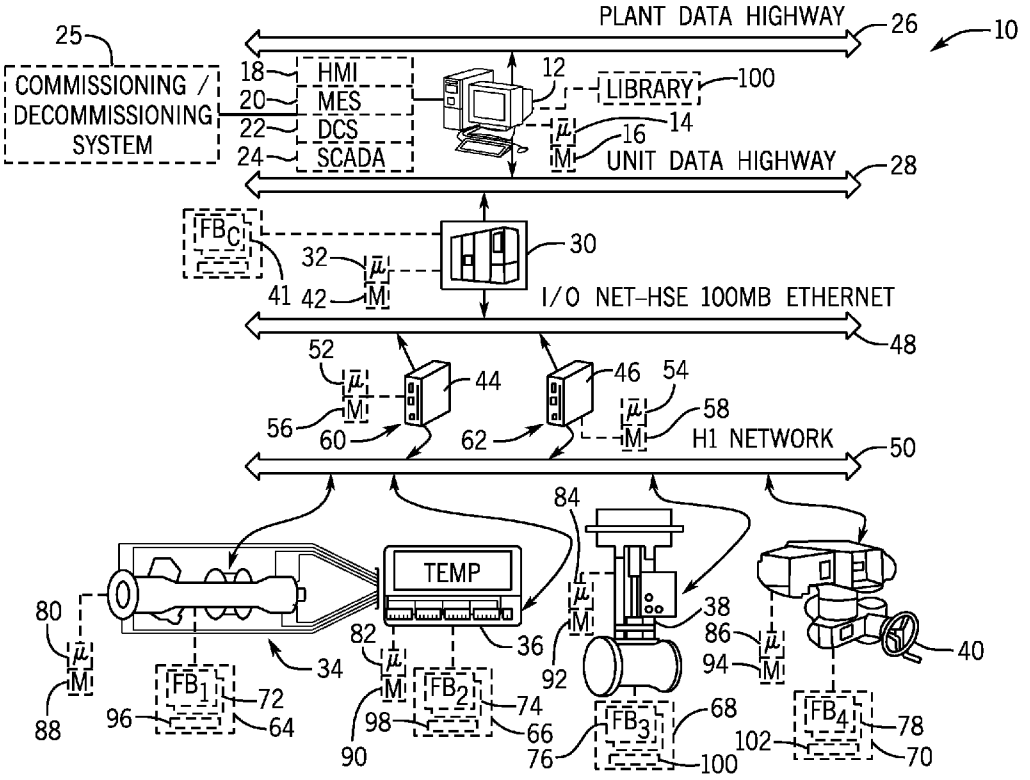
(57) ABSTRACT

The embodiments described herein include a system and a method. In one embodiment, a system includes an industrial controller configured to control a first field device. The first field device includes an actuator and a positioner coupled to the actuator. The positioner is configured to position the actuator. The first field device is configured to detect an undesired condition and to communicate the undesired condition to the industrial controller by using a ReadBack facility of the first field device.



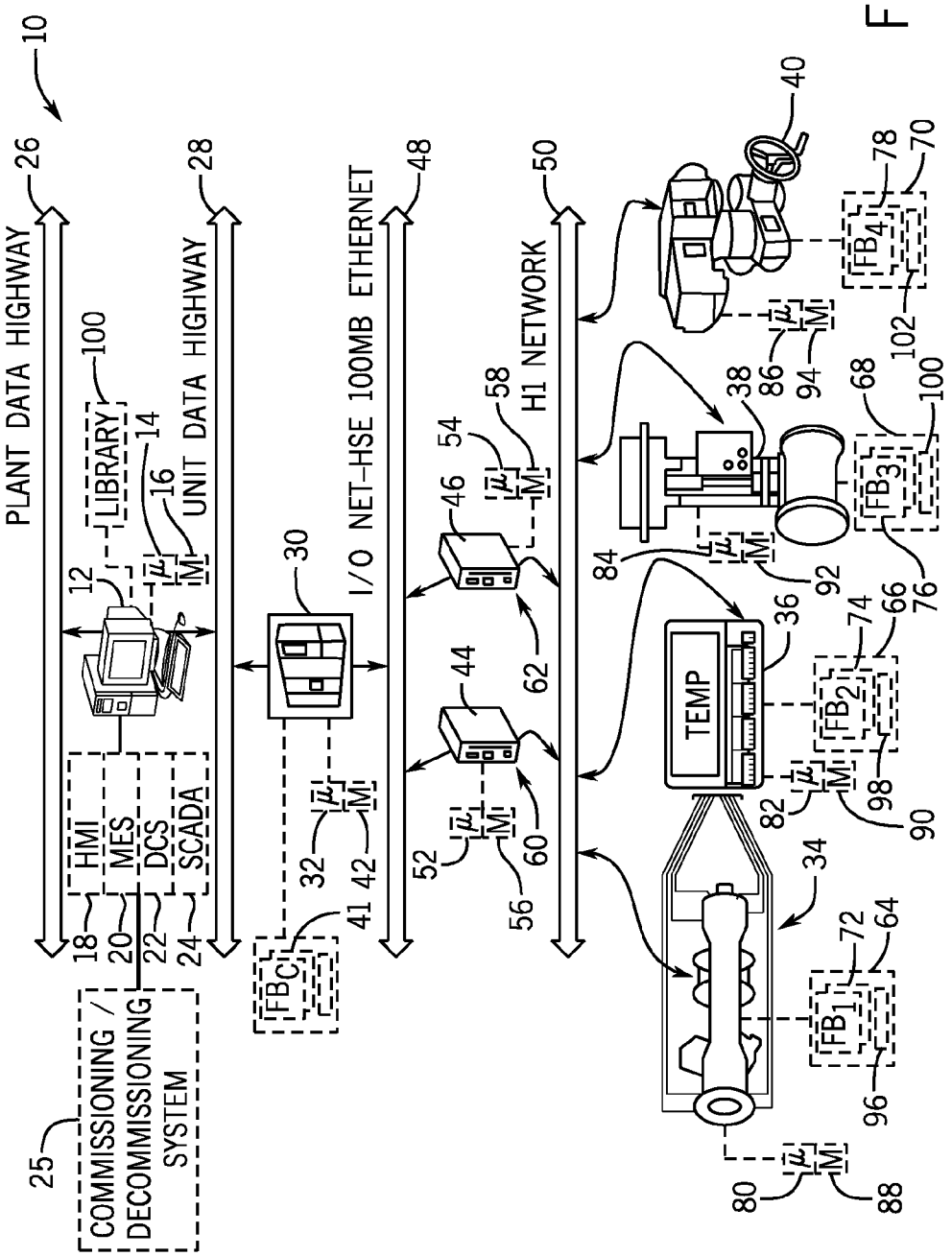

10
PLANT DATA HIGHWAY
26
LIBRARY
100
14
16
UNIT DATA HIGHWAY
28
12
30
I/O NET-HSE 100MB ETHERNET
48
46
54
58
H1 NETWORK
50
40
78
70
102
38
86
94
68
100
84
92
66
76
74
36
TEMP
82
98
90
34
72
64
96
80
88
HMI
MES
DCS
SCADA
18
20
22
24
25
COMMISSIONING / DECOMMISSIONING SYSTEM
FB1
FB2
FB3
FB4
FBC
32
41
42
52
56
60
62
44

FIG. 1

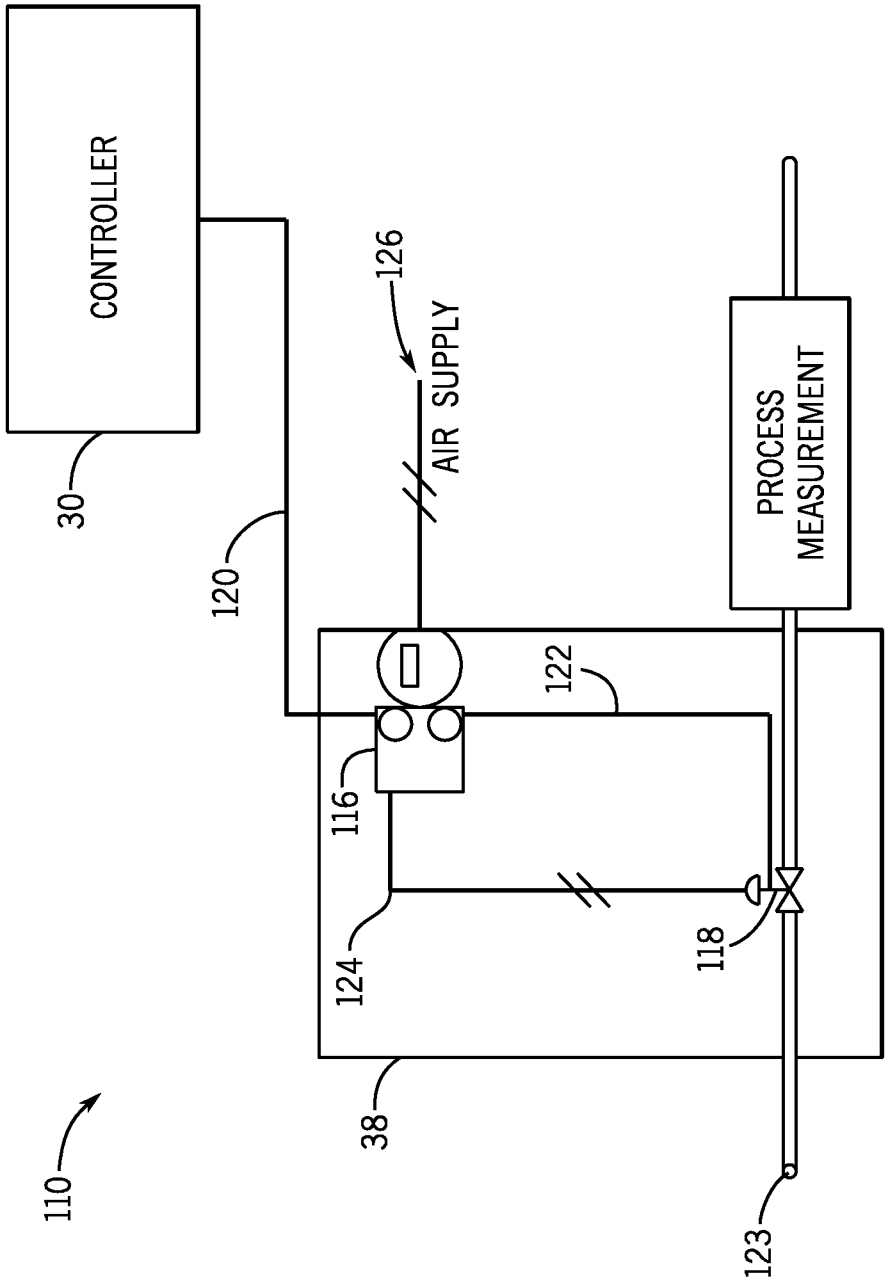

CONTROLLER
30
120
126
AIR SUPPLY
PROCESS MEASUREMENT
122
116
124
118
38
110
123

FIG. 2

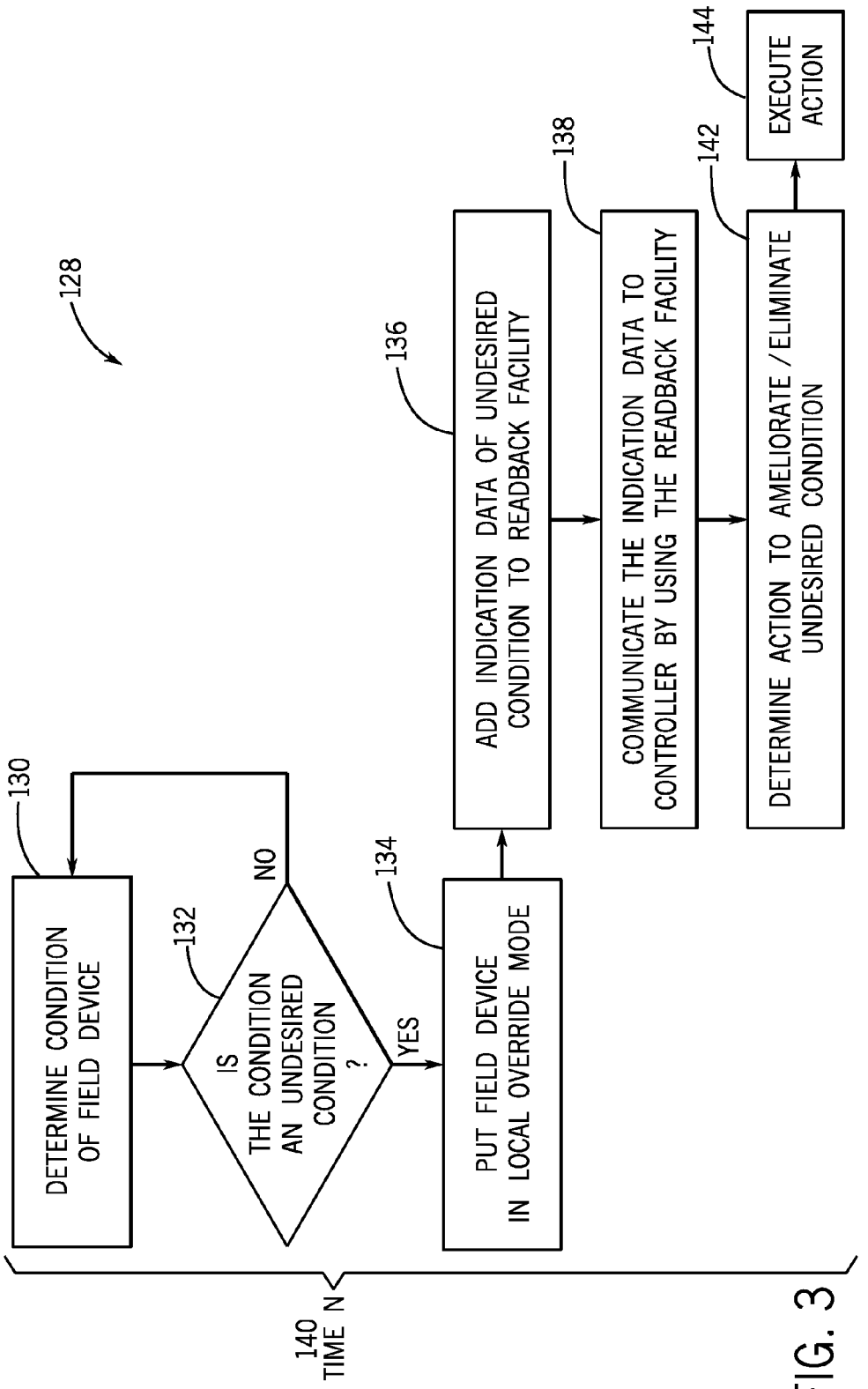
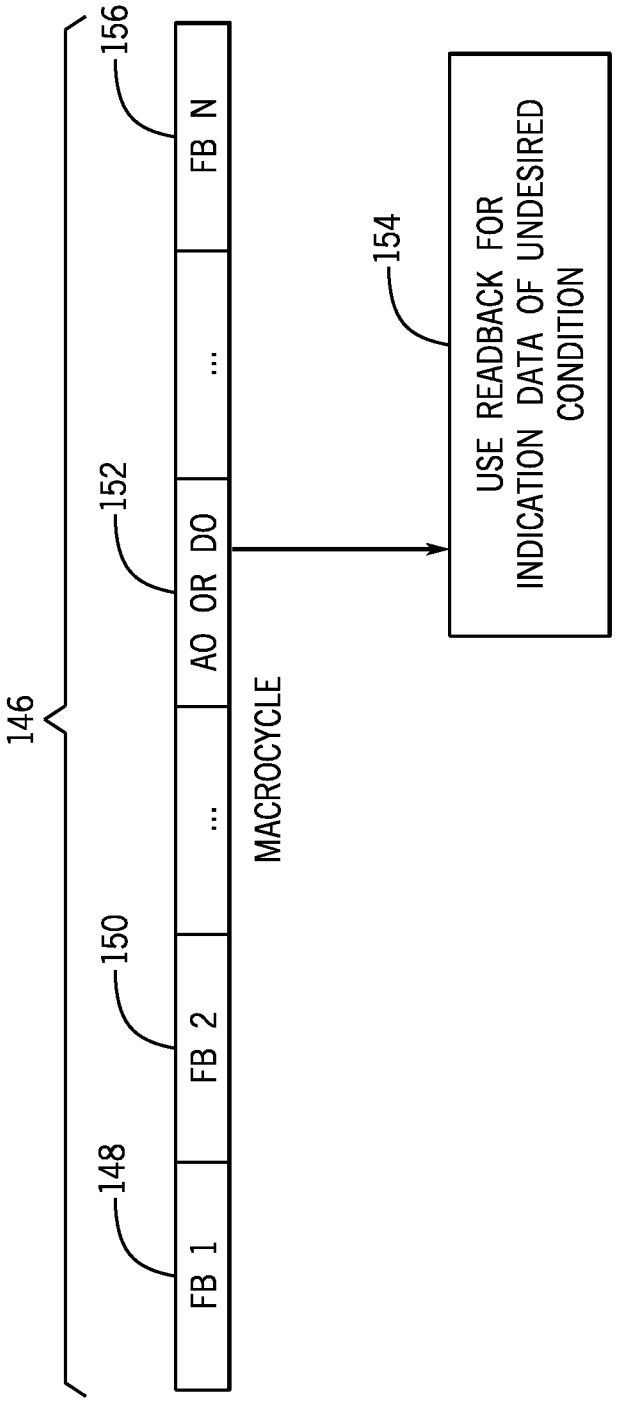

128
130
DETERMINE CONDITION OF FIELD DEVICE
132
IS THE CONDITION AN UNDESIRED CONDITION ?
NO
YES
134
PUT FIELD DEVICE IN LOCAL OVERRIDE MODE
136
ADD INDICATION DATA OF UNDESIRED CONDITION TO READBACK FACILITY
138
COMMUNICATE THE INDICATION DATA TO CONTROLLER BY USING THE READBACK FACILITY
142
DETERMINE ACTION TO AMELIORATE / ELIMINATE UNDESIRED CONDITION
144
EXECUTE ACTION
140
TIME N

FIG. 3

FIG. 4


146
148
FB 1
150
FB 2
...
152
AO OR DO
...
156
FB N
MACROCYCLE
154
USE READBACK FOR INDICATION DATA OF UNDESIRED CONDITION

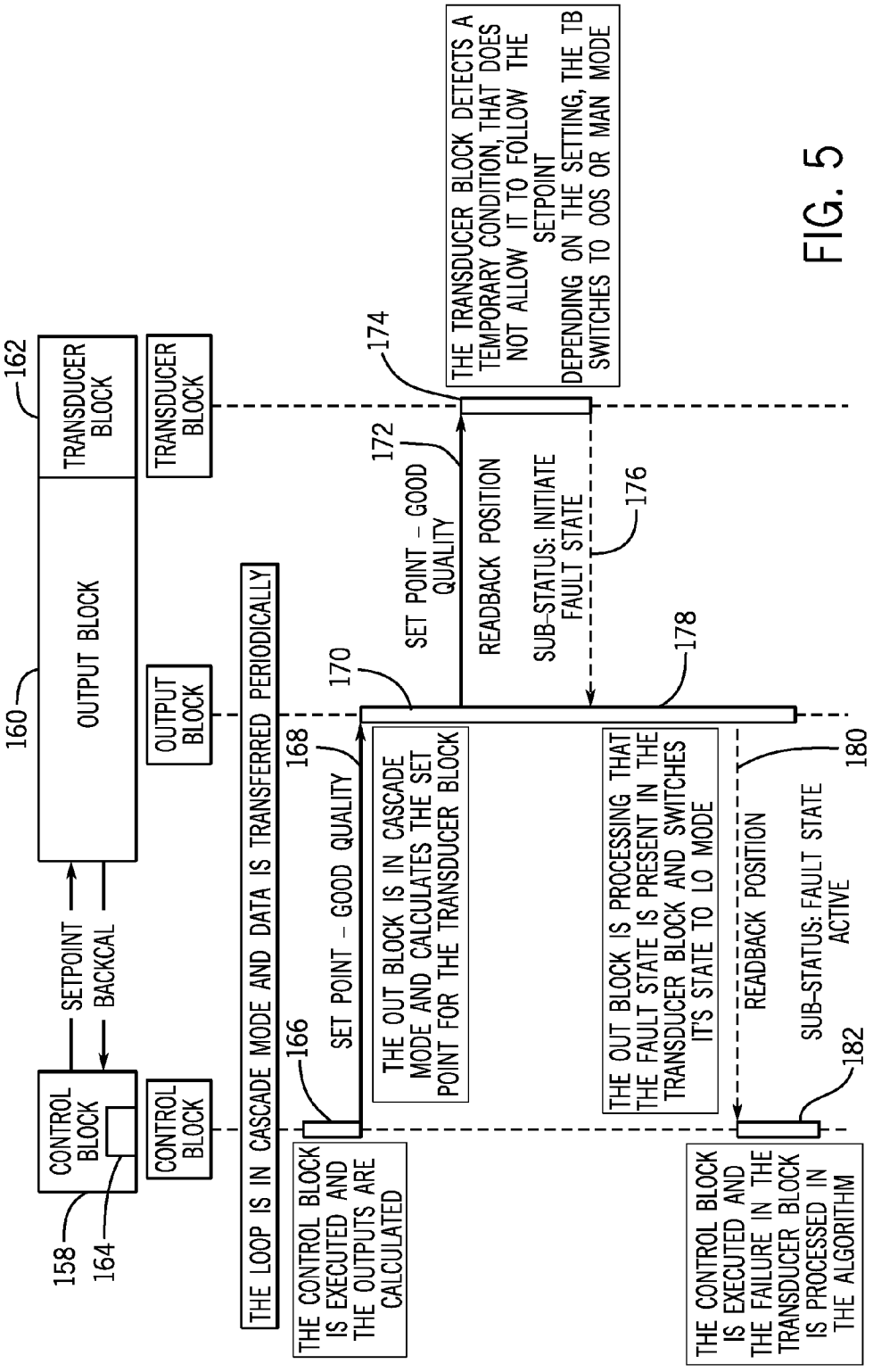

CONTROL BLOCK
OUTPUT BLOCK
TRANSDUCER BLOCK
SETPOINT
BACKCAL
158
164
160
162
CONTROL BLOCK
OUTPUT BLOCK
TRANSDUCER BLOCK
THE LOOP IS IN CASCADE MODE AND DATA IS TRANSFERRED PERIODICALLY
166
168
170
172
174
176
178
180
182
SET POINT – GOOD QUALITY
THE CONTROL BLOCK IS EXECUTED AND THE OUTPUTS ARE CALCULATED
THE OUT BLOCK IS IN CASCADE MODE AND CALCULATES THE SET POINT FOR THE TRANSDUCER BLOCK
SET POINT – GOOD QUALITY
READBACK POSITION
SUB-STATUS: INITIATE FAULT STATE
THE TRANSDUCER BLOCK DETECTS A TEMPORARY CONDITION, THAT DOES NOT ALLOW IT TO FOLLOW THE SETPOINT
DEPENDING ON THE SETTING, THE TB SWITCHES TO OOS OR MAN MODE
THE OUT BLOCK IS PROCESSING THAT THE FAULT STATE IS PRESENT IN THE TRANSDUCER BLOCK AND SWITCHES IT'S STATE TO LO MODE
READBACK POSITION
SUB-STATUS: FAULT STATE ACTIVE
THE CONTROL BLOCK IS EXECUTED AND THE FAILURE IN THE TRANSDUCER BLOCK IS PROCESSED IN THE ALGORITHM

FIG. 5

SYSTEMS AND METHODS FOR FIELD DEVICE FEEDBACK

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to systems and methods for feedback of certain devices, and more specifically, in field devices.

[0002] Certain systems, such as industrial control systems, may include capabilities that enable the system to detect and correct undesired conditions within the system. For example, the Foundation Fieldbus protocol provides smart field devices with the ability to communicate conditions that are related to the hardware and/or software health of the device to the control system's control strategy. However, when the undesired condition is not part of the hardware or software, the smart field device by itself may be unable to communicate the presence of the undesired condition. This could include conditions like insufficient air pressure to a pneumatic digital valve.

BRIEF DESCRIPTION OF THE INVENTION

[0003] Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0004] In a first embodiment, a system includes an industrial controller configured to control a first field device. The first field device includes an actuator and a positioner coupled to the actuator. The positioner is configured to position the actuator. The first field device is configured to detect an undesired condition and to communicate the undesired condition to the industrial controller by using a ReadBack facility of the first field device.

[0005] In a second embodiment, a method includes determining a state of a field device. And if the state includes an undesired condition, then deriving an indication of an undesired condition and adding the indication of the undesired condition to a ReadBack facility. The method further includes communicating the indication to a control block.

[0006] In a third embodiment, a non-transitory tangible computer-readable medium storing a plurality of instructions executable by a processor of an electronic device, the instructions include instructions to determine a state of a field device. If the state includes an undesired condition, the instructions also include instructions to derive an indication of the undesired condition. The instructions further include instructions to add the indication of the undesired condition to a ReadBack facility and instructions to communicate the indication to a control block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. **1** is a schematic diagram of an embodiment of an industrial control system, including an industrial controller and a valve;

[0009] FIG. **2** is a schematic diagram of an embodiment of an industrial controller and a pneumatic valve;

[0010] FIG. **3** is a flowchart of an embodiment of a process suitable for detecting, communicating, and ameliorating an undesired condition in field devices;

[0011] FIG. **4** is a timing diagram of an embodiment of an Output function block using a ReadBack facility to indicate an undesired condition during a macrocycle; and

[0012] FIG. **5** is an information flow diagram showing embodiments of information being transferred between a control block, output block, and transducer block.

DETAILED DESCRIPTION OF THE INVENTION

[0013] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0014] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0015] Certain industrial control systems include industrial controllers suitable for interfacing with a variety of field devices, such as sensors, pumps and valves. For example, an industrial controller may direct a pneumatic valve to set the valve's actuator at a certain position to affect the flow through the valve. However, desired functioning of the pneumatic valve may be affected by undesired conditions, such as insufficient air pressure used to control the valve or a foreign object in the valve. In order for the industrial controller to take appropriate ameliorative action, undesired conditions may be detected and communicated to the industrial controller.

[0016] In field devices compliant with a Foundation Fieldbus protocol, the field devices will have the capability to transmit feedback to the industrial controller issues that relate to the hardware and/or software of the device on a periodic basis. For example, the Foundation Fieldbus protocol, International Electrotechnical Commission (IEC) 61804, is a two-way communication system, which interconnects various fieldbus devices such as sensors, pumps, valves, industrial controllers, and the like, via a local area network (LAN). However, the Foundation Fieldbus protocol does not include the same feedback ability for communicating undesired conditions, such as insufficient air pressure, because the field device itself is not defective or faulted. The insufficient air pressure may be attributed to an air supply external to the field device. Other undesired conditions may include low actuation amperage, a sticky valve, or a foreign object in a valve. It may be plausible to implement a solution that uses additional function blocks to specifically monitor parameters like supply air pressure. However, the use of the additional function

blocks requires additional processing power and bandwidth, which may result in slower execution. In some cases the host may poll for an undesired condition during a specified time, often close to **30** or more seconds. A "macrocycle," as discussed herein, may refer to a cycle of scheduled function block execution, scheduled communication time, and a portion of time reserved for asynchronous communications (e.g., alerts and/or downloads) by devices on a communications segment (e.g., an H1 segment).

[0017] The disclosed embodiments provide a system and method to provide field device feedback, especially for those parameters not included in the health definitions of the Foundation Fieldbus protocol. In one embodiment, by utilizing the ReadBack facility of Foundation Fieldbus function blocks, the present techniques are able to detect and communicate an undesired fault condition and recovery from the fault condition to the industrial controller without the use of additional or custom function blocks and without the need for additional bandwidth within the macrocycle. Furthermore, because when a field device is not functioning as desired due to an undesired condition, it may be very useful to take ameliorative action as quickly as possible. If the techniques described herein are enabled during commissioning, the disclosed embodiments may be able to almost immediately switch to an OOS (Out of Service), Manual, or Local Override Mode, which signals to the industrial controller that the field device is not responding because a fault state is active. The industrial controller can then take further actions based on feedback, which may include information concerning undesired field device conditions (e.g., low actuation air pressure, low actuation amperage, sticky valve, or foreign object in a valve).

[0018] Turning to FIG. **1**, an embodiment of an industrial control system **10** is depicted. The industrial control system **10** may include a computer system **12** suitable for executing a variety of field device configuration and monitoring applications, and for providing an operator interface through which an engineer or technician may monitor the components of the control system **10**. Accordingly, the computer **12** includes a processor **14** that may be used in processing computer instructions, and a memory **16** that may be used to store computer instructions and other data. The computer system **12** may include any type of computing device or a combination of computing devices suitable for running software applications, such as a laptop, a workstation, a tablet computer, or a handheld portable device (e.g., personal digital assistant or cell phone). Indeed, the computer system **12** may include any of a variety of hardware and/or operating system platforms. In accordance with one embodiment, the computer **12** may host an industrial control software, such as a human-machine interface (HMI) software **18**, a manufacturing execution system (MES) **20**, a distributed control system (DCS) **22**, and/or a supervisor control and data acquisition (SCADA) system **24**. A commissioning/decommissioning system **25** may be included in the HMI **18**, MES **20**, DCS **22**, and/or SCADA **24**, and used to commission and/or decommission certain devices, as described in more detail below. The HMI **18**, MES **20**, DCS **22**, SCADA **24** and/or commissioning/decommissioning system **25**, may be stored as executable code instructions on non-transitory tangible computer readable media, such as the memory **16** of the computer **12**. For example, the computer **12** may host the ToolboxST™ and/or ControlST™ software, available from General Electric Company, of Schenectady, N.Y.

[0019] Further, the computer system **12** is communicatively connected to a plant data highway **26** suitable for enabling communication between the depicted computer **12** and other computers **12** in the plant. Indeed, the industrial control system **10** may include multiple computer systems **12** interconnected through the plant data highway **26**. The computer system **12** may be further communicatively connected to a unit data highway **28**, suitable for communicatively coupling the computer system **12** to an industrial controller **30**. The industrial controller **30** may include a processor **32** and memory **42** suitable for executing a control strategy useful in automating a variety of plant equipment, such as a turbine system **34** (e.g., gas turbine, steam turbine, water turbine, wind turbine etc.), a power generation system, a heat recovery steam generator (HRSG), a gas treatment system, a temperature sensor **36**, a valve **38**, and a pump **40**. This may be implemented through the use of one more function blocks **41** executable by the industrial controller **30**. In some embodiments, the industrial controller **30** may be a proportional-integral-derivative (PID) controller. Accordingly, the PID controller may be implemented by a PID function block. The function blocks **41** may include computer instructions or computer logic executable by processor **32**. The industrial controller **30** may communicate with a variety of field devices, including but not limited to flow meters, pH sensors, temperature sensors, vibration sensors, clearance sensors (e.g., measuring distances between a rotating component and a stationary component), pressure sensors, pumps, actuators, valves, and the like. In some embodiments, the industrial controller **30** may be a Mark™ VIe controller system, available from General Electric Co., of Schenectady, N.Y., including a triple modular redundant (TMR) controller **30** having three cores (e.g., R, S, T) suitable for redundant controller operations. For example, the R, S, and T cores may vote to determine control actions.

[0020] In the depicted embodiment, the turbine system **34**, the temperature sensor **36**, the valve **38**, and the pump **40** are communicatively connected to the industrial controller **30** by using linking devices **44** and **46** suitable for interfacing between an I/O network **48** and an H1 network **50**. For example, the linking devices **44** and **46** may include the FG-100 linking device, available from Softing AG, of Haar, Germany. As depicted, the linking devices **44** and **46** may include processors **52** and **54**, respectively, useful in executing computer instructions, and may also include memory **56** and **58**, useful in storing computer instructions and other data. In some embodiments, the I/O network **48** may be a 100 Megabit (MB) high speed Ethernet (HSE) network, and the H1 network **50** may be a 31.25 kilobit/second network. Accordingly, data transmitted and received through the I/O network **48** may in turn be transmitted and received by the H1 network **50**. That is, the linking devices **44** and **46** may act as bridges between the I/O network **48** and the H1 network **50**. For example, higher speed data on the I/O network **48** may be buffered, and then transmitted at suitable speed on the H1 network **50**. Accordingly, a variety of field devices may be linked to the industrial controller **30** and to the computer **12**. For example, the field devices **34**, **36**, **38**, and **40** may include industrial devices, such as Fieldbus Foundation devices that include support for the Foundation H1 bi-directional communications protocol. The field devices **34**, **36**, **38**, and **40** may also include support for other communication protocols, such

as those found in the HART® Communications Foundation (HCF) protocol, and the Profibus Nutzer Organization e.V. (PNO) protocol.

[0021] Each of the linking devices **44** and **46** may include one or more segment ports **60** and **62** useful in segmenting the H1 network **50**. For example, the linking device **44** may use the segment port **60** to communicatively couple with the devices **34** and **36**, while the linking device **46** may use the segment port **62** to communicatively couple with the devices **38** and **40**. Distributing the input/output between the field devices **34**, **36**, **38**, and **40**, by using, for example, the segment ports **60** and **62**, may enable a physical separation useful in maintaining fault tolerance, redundancy, and improving communications time.

[0022] Each field device **34**, **36**, **38**, and **40** may include a respective device description (DD) file, such as the depicted DD files **64**, **66**, **68**, and **70**. The DD files **64**, **66**, **68**, and **70** may be written in a device description language (DDL), such as the DDL defined in the International Electrotechnical Commission (IEC) 61804 standard. In some embodiments, the files **64**, **66**, **68**, and **70** are tokenized binary files. That is, the DD files **64**, **66**, **68**, and **70** may include data formatted in a tokenized binary format useful in reducing the size of the DD files **64**, **66**, **68**, and **70**. The DD files **64**, **66**, **68**, and **70** may each include one or more function blocks **72**, **74**, **76**, and **78**. The function blocks **72**, **74**, **76**, and **78** may include computer instructions or computer logic executable by processors **80**, **82**, **84**, and **86**. Indeed, the function blocks **72**, **74**, **76**, and **78** may be instantiated into memory **88**, **90**, **92**, **94**, and then executed by the processors **80**, **82**, **84**, and **86**, respectively. Each of the DD files **64**, **66**, **68**, and **70** may also include device information **96**, **98**, **100**, and **102**, such as manufacturer identification (ID), device type, device revision, DD revision, and/or update revision, which may be used during commissioning or decommissioning by the commissioning/decommissioning system **25**. In this way, the field devices **34**, **36**, **38**, and **40** may contribute control logic and other computer instructions towards the execution of processes in the industrial process control system **10**.

[0023] In one example, a placeholder may be created by the commissioning/decommissioning system **25**. The placeholder may be an object stored in memory **16** that represents the field device **38**. Accordingly, a user may pre-commission a system by creating one or more of the placeholder, each of the placeholders representing the device **38**, and then use the placeholder(s) during commissioning of the physical field device **38**. The placeholder may include physical device (PD) tag, manufacturer ID, device type, device revision, DD revision, and/or update revision representative of the field device **38**. The PD tag may include a device name useful in identifying the device **38**. Likewise, the manufacturer ID may include information identifying the manufacturer of the device **34**. The device type may be suitable for identifying the type of device (e.g., valve, sensor, actuator), while the device revision may be a version number indentifying the device version. Likewise, the DD revision may identify the DD version, such as a DD file version included in the device **38**. It should be appreciated that in another embodiment, the device **38** may be commissioned without using the placeholder. In one embodiment, field device **38** may be a flow control device, such as a valve, flow and/or pressure regulator, flow restrictor or any combination thereof. For example the field device **38** may be a valve such as a pneumatic actuated valve, a hydraulic actuated valve, an electricity driven valve or any combination thereof. As described above, undesired conditions may hinder the operation of the field device **38**. Accordingly, FIG. **2** describes an exemplary pneumatic device as well as undesired conditions, such as insufficient air pressure.

[0024] FIG. **2** is a schematic diagram illustrating an embodiment of the industrial controller **30** controllably coupled to the pneumatic valve **38** of FIG. **1**. The pneumatic valve **38** may include a valve body, a fluid path through the valve body, an inlet, and outlet, and a valve member that move in the fluid path to open and close the flow path. In addition, the pneumatic valve **38** may includes a positioner **116** and an actuator **118**. The positioner **116** may be configured to receive a desired valve position from the controller **30** and provide a signal, such as air, to the actuator **118**. An exemplary positioner **116** may be General Electric's Masoneilan SVI digital valve positioner with built-in magnetic position sensing and pressure sensors, available from General Electric Co., of Schenectady, N.Y. The actuator **118** may then change the signal into mechanical energy to move the valve member to the desired position. The valve member may move in either a linear or rotary manner. In a linear valve, the throughput of the valve may be changed by moving the valve member linearly in the valve. In a rotary valve, the throughput of the valve may be changed by rotating the valve member in the valve.

[0025] The actuator **118** may be different types including wheel and axle, pneumatic, hydraulic, solenoid, screw and manual. For example, in a pneumatic valve **38**, the positioner **116** may increase or decrease the air supplied to the actuator **118** based on the desired valve position. Accordingly, the air supplied to the actuator **118** may move the valve member to the desire valve position. More specifically, in a functioning pneumatic valve **38**, the industrial controller **30** may send control actions through conduit **120**, according to a control strategy for the control system, to the positioner **116**, which includes a desired valve position. The positioner **116** is then able to determine the current position of the actuator **118**, for example, by using conduit **122**, and determine the air pressure to supply to the actuator **118** to move the valve member to the desired position. The positioner **16** may the supply the determined amount of air from the air supply **126**. In the depicted embodiment, the air supply **126** is located external to the pneumatic valve **38**. The air may then be applied to the actuator **118** through fluid conduit **124** and the position of the valve member may be changed as desired.

[0026] An undesired condition may arise when the positioner **116** is unable to receive sufficient air pressure from the air supply **126**, resulting in the positioner **116** having difficulty moving the actuator **118** to the desired position. In some cases, the industrial controller **30** may not be aware of the undesired condition (e.g., low air supply pressure) because the undesired condition is external to the valve **38** and thus not included in hardware and/or software health definitions of the valve **38**. To account for this, the user may extend the control strategy and execute additional function blocks to collect the information; however, this may slow down the control process and reduce the quality of control. If the undesired condition is unaccounted for, the controller **30** may continue following the control strategy and operate as if the valve is in the correct position. This can cause undesired behavior in the system **10**. For example, if the controller **30** derives that the valve **38** is more open than it actually is, this could result in a back up in pipe **123**. In addition, when the controller **32** is a PID controller, if the controller **32** is unaware that the valve **38** is unable to move to follow the setpoint, the controller **32** may

continue to integrate causing the error to build up the control output value, which may make the recovery process difficult. Thus, undesired conditions may be detected and communicated back to the industrial controller **30** as quickly as possible to, for example, more properly actuate the valve **38** or use a backup valve.

[0027] The techniques described below may be used in other field devices **38** including different types of valves (e.g., electric, electro-pneumatic, hydraulic, and electro-hydraulic valves), flow meters, pH sensors, temperature sensors, vibration sensors, clearance sensors (e.g., measuring distances between a rotating component and a stationary component), pressure sensors, pumps, and actuators. Similar to insufficient air pressure in the pneumatic valve **38**, undesired conditions may not be included in the hardware and/or software definitions of the field device. For example, an electric valve that relies on electricity to activate the valve may suffer from an undesired condition such as insufficient power or incorrect frequency of the input from an external power source. Similarly, a wind pump that relies on wind power to supply energy to the pump may suffer from an undesired condition such as insufficient wind flow. Accordingly, FIG. **3** describes one technique to communicate the undesired conditions to the controller **30**.

[0028] FIG. **3** is a flowchart of an embodiment of a process **128** suitable for detecting, communicating, and ameliorating an undesired condition using an embodiment of the field device feedback utilizing, for example, a ReadBack facility. As described above, the field device may be commissioned by the commissioning/decommissioning system **25** using a placeholder representative of the field device with the ReadBack facility.

[0029] The process **128** may be implemented by using computer instructions stored in a non-transitory computer-readable medium, such as the memory of a computer, server, laptop, tablet, cell phone, mobile device, or similar processing or computing device. The process **128** may begin by determining (block **130**) the condition of the field device **38**. The condition of the field device **38** may be determined by various sensors in the field device **38**. For example, in the pneumatic valve **38** described in FIG. **2**, a condition of "insufficient air pressure" may be determined when a sensor in the air supply **116** detects insufficient pneumatic pressure being supplied. Similarly, another condition of "foreign object present" may be determined when a sensor located within the pipe **123** detects a foreign object within the pipe. Other sensors in the pneumatic device **38** may be used to determine other conditions such as "valve not moving properly" when the vale is jamming, sticking, or generally not responding properly. A condition of "functioning properly" may be determined when none of the sensors in the field device **38** detect an issue.

[0030] The process **128** then determines whether (decision block **132**) the condition is an undesired condition. As will be described in more detail with reference to FIG. **5**, one embodiment utilizes a function block, such as a transducer function block, to determine whether the condition has to be reported. If the condition is not an undesired condition, the process **128** returns to block **130** and continues to monitor the condition (e.g., "insufficient air pressure" or "functioning properly") of the field device. If the condition of the field device is an undesired condition, the process **128** puts (block **134**) the field device (e.g., valve **38**) into a fault state such as Local Override Mode, which immediately stops the field device from trying to follow the industrial controller's instructions.

[0031] Next, the process **128** may add (block **136**) indication data of the undesired condition to the ReadBack Facility. As will be described in more detail in reference to FIG. **5**, the ReadBack Facility may be part of an Output function block that allows for the Output function block to feedback a signal to a control block, for example, through a sub-status/category. This may be implemented using the BKCAL_OUT and BKCAL_IN parameters. Specifically, Block **136** may be implemented by writing to the BKCAL_OUT parameter on the Output function block. The process **128** then uses the ReadBack facility to communicate (block **138**) the indication data to the industrial controller **30**, which may be implemented by reading the BKCAL_IN parameter on the control block. Similarly, if the undesired condition disappears, the process **128** may then use the ReadBack facility to communicate a status of good so that the control algorithm may resume normal control operations.

[0032] In one embodiment, the blocks **130**, **134**, **136**, and **138** may execute within a Time N **140**. In some embodiments, Time N **140** is 1-2 macrocycles, where a "macrocycle" refers to a cycle of scheduled function block execution, scheduled communication time, and a portion of time reserved for asynchronous communications. In other words, a macrocycle may be one control loop execution. The Foundation Fieldbus protocol may allow macrocycles to be configured at between 10-250, 100-500, 250-1000, 750-3000 or more milliseconds. Thus, by using the ReadBack techniques disclosed herein, the Time N **140** may be as fast as 10-250 milliseconds or 250-3000 milliseconds. The techniques herein enable a quicker notification of an undesired condition because it enables the undesired condition to be reported in 1-2 loop executions as compared to additional custom function blocks, which may poll for the undesired condition after a specified time, such as 30 seconds. A more detailed explanation of the functioning of the ReadBack facility within a macrocycle is described in FIG. **4**.

[0033] FIG. **4** is diagram of an embodiment of a macrocycle **146** including an Output function block (Analog or Digital) **152** having ReadBack facility for indicating the presence of an undesired condition. During the execution of the macrocycle **146**, one or more function blocks may execute at desired time slots. As an example, these function blocks may include Alarm Detection Function Blocks, Analog Input Function Blocks, Calculation/Logic Function Blocks, Filter Function Blocks, and Arithmetic Function Blocks. In the depicted embodiment, the macrocycle **146** begins by executing function block **1** (FB**1**) at time slot **148** followed by function block **2** (FB**2**) at time slot **150**, and so on. When the macrocycle reaches the Output function block (e.g., Analog Output (AO) or the Digital Output (DO)) time slot **152** and an undesired condition is detected, the Output function block may use the ReadBack facility to indicate (block **154**) the undesired condition. The macrocycle **146** may continue executing function blocks until reaching function block N (FBN) at time slot **156**. Then, the macrocycle **146** may repeat execution of function blocks, for example, by starting over with FB**1** at time slot **148**. By using the ReadBack facility, the techniques described herein provide for deterministic execution of processes associated with the controller **30**. In other words, control may be provided at substantially the same execution time, even when undesired conditions are detected, and control actions may be

modified correlative with the detected conditions. Accordingly, the undesired conditions may be overcome by control actions or notifications may be provided, thus improving the safety of the system **10**.

[0034] Referring back to FIG. **3**, once the industrial controller **30** receives the indication data, the process **128** may determine (block **142**) at least one action to take in order to ameliorate or eliminate the undesired condition. For example, a backup valve may be used as an alternative to the malfunctioning valve, fluids may be transferred via an alternate pipe, alarms may be set, other systems may be notified, and so on. Finally, the process **128** may execute (**144**) the action to ameliorate or eliminate the undesired condition. As will be described in further detail in FIG. **5**, block **142** and **144** may be executed in the control block.

[0035] FIG. **5** is an information diagram showing embodiments of an information flow between a control function block **158**, output function block **160**, and transducer function block **162** in an exemplary embodiment. The information diagram may be executed in one macrocycle or one control loop. In some embodiments, the control block **158** is executed using the industrial controller **30** of FIG. **1**. The industrial controller **30** is communicatively coupled to a first field device, such as the valve **30** having the output block **160** and the transducer block **162**. In the depicted embodiment, the output block **160** and the control block **158** may communicate through one or more fieldbus publisher/subscriber (periodic) communication connections, as described above. The output block **160** and the transducer block **162** may be programmatically used in certain control algorithms so that data computed by using one or more function blocks may be used as inputs to other function blocks. It should be appreciated that, alternatively, all of the function blocks may be included in the same field device, e.g., valve **38**, and/or in the controller **30**.

[0036] To better illustrate the information flow, the function blocks **158**, **160**, and **162** can be described in relation to the pneumatic valve **38** in FIG. **2**, and may include Foundation Fieldbus capabilities. The industrial controller **30**, through the control function block **158**, may implement a control strategy **164** to guide the functioning of the rest of the control system. Alternatively, the control function block **158** may be included in the field device **38**. In some embodiments, the control block **158** may be a proportional-integral-derivative (PID) control block **158**. Following the control strategy **164**, the control block **158** may begin by calculating (process block **166**) a desired valve position and passing (data flow **168**) the information to the output function block **160**, for example, as a first SetPoint. Because the output function block **160** may be in Cascade Mode (e.g., a mode that uses a master-slave configuration), it may use the first SetPoint to decide the value (process block **170**) for a second SetPoint and pass (data flow **172**) the second SetPoint to the transducer function block **162**. This second SetPoint may be used to translate a standard fieldbus value to a value (analog or digital) that can be used by the transducer function block **162**. In normal operation, as described above, the valve may move the actuator and the valve member to the desired position.

[0037] However, in the case of an undesired condition, the transducer function block **162** through the valve positioner may detect the condition and switch (process block **174**) the transducer block **162** to Out-of-Service or Manual mode. In Out-of-Service mode, the function block is inactive and the output of the function block maintains the last value or a failure action value. In Manual mode, the output of the function block remains unchanged, until a new value is set by an operator. In this embodiment, the valve positioner **116** monitors the undesired condition (i.e. insufficient supply air pressure). The valve positioner **116** and/or other sensors and actuators can be used to monitor other/multiple undesired conditions, such as insufficient hydraulic pressure, insufficient wind power, or improper electric power (e.g. incorrect frequency). Also, potential undesired conditions can be monitored at the same time. The transducer block **162** may then use its ReadBack facility to return (data flow **176**) a sub-status of Initiate Fault State. Once the output block **160** receives the Initiate Fault State sub-status, it may switch (process block **178**) the output function block **160** from Cascade mode into Out of Service, Manual, or Local Override mode. In the Foundation Fieldbus protocol, these modes are part of output function blocks including the Analog Output (AO), the Digital Output (DO), or a combination thereof. The new mode may stop the output block **160** from using the first SetPoint and may instead set the second SetPoint to a specified value. Thus, the output block **160** may stop calculating the second SetPoint.

[0038] The output block **160** may the use the ReadBack facility to return (data flow **180**) a sub-status of Failed State Active to notify the control function block **158** of the undesired condition in the field device. Additionally or alternatively, output function block **160** may return a sub-status of NotInvited or NotSelected. The ReadBack facility may be implemented by the BKCAL_OUT parameter on the output function block **160**. The BKCAL_OUT parameter is used to communicate a value and a status, including sub-status, that may be required by the BKCAL_IN of another function block. The BKCAL_OUT parameter may be communicatively coupled to the BKCAL_IN parameter on the control function block **158**. The two function blocks may communicate through a publish/subscribe protocol, which allows for the communications to be fast and deterministic in schedule. The BKCAL_OUT parameter may be used to help provide smooth mode transfer when the mode on the output function block **160** is changed by providing a value and status, including sub-status, to the control function block **158**. The disclosed embodiments may instead use the sub-status in the BKCAL_OUT parameter to inform the control function block **158** that an undesired condition is present. In addition, the output block **160** may return a status that indicates the limited SetPoint so that recovery may be bumpless.

[0039] Without the disclosed embodiments, when the Output function block **160** is assigned to a field device, such as a valve, the BKCAL_OUT parameter may be used to communicate information such as actuator position. In other words, without the disclosed embodiments, the BKCAL_OUT parameter may be used to communicate conditions affecting mode and status that are related to the hardware and/or software health of the field device using the ReadBack facility. The disclosed embodiments, on the other hand, use the Output function block **160** that communicates undesired conditions not included in the hardware and/or software health of the field device, such as the insufficient air pressure being supplied by the air supply **126** or other conditions related to systems external to the field device. Thus, the disclosed embodiments have adapted the BKCAL_OUT parameter to communicate conditions that previously were either not being communicated to the control strategy or were communicated using additional and/or custom function blocks to communicate to the control strategy.

[0040] Once the sub-status is read by the control function block **158**, the control function block **158** may automatically use the control strategy **164** to determine an ameliorative action (process block **182**). For example, the control function block **158** may use a second field device, like an alternative valve, as a backup. This provides for redundancy in the operation for the first field device. Other ameliorative actions include shutting down a pump, disallowing the process to start, issuing alerts, communicating with an operator or with other systems. In addition, when the control function block **158** is a PID control function block **158**, the PID control function block **158** may stop integrating the error and changing the SetPoint. This may assist in a faster recovery because once recovered, the Output Block **160** will resume using the most recent SetPoint. Accordingly, it should be appreciated that the integrating should cease as quickly as possible, which may be accomplished through the techniques described herein. Specifically the integrating may cease within one macrocycle.

[0041] Similar to reporting an undesired condition, recovery may be accomplished within one macrocycle. In the recovery process, the Output function block **160** may notify the control function block **158** using the same ReadBack facility. Accordingly, the control function block **158** may resume normal operation within one macrocycle or one control loop execution.

[0042] In other embodiments, such as in when the function blocks are in a cascade loop, the control function block **158** may act similarly to the Output function block **160** and use its ReadBack facility to notify another control function block **158** of the undesired condition. In other words, the presence of the undesired condition may be passed between coupled control function blocks **158** through the ReadBack facility. Accordingly, similar to the techniques described above, the time to communicate the presence of an undesired condition between the control function blocks **158** may be one macrocycle **146**.

[0043] Technical effects of the described embodiments include efficiently enabling the field device **38** to communicate the presence of an undesired condition, such as insufficient pneumatic pressure, to a controller **30**. In particular, the field device **38** may be able to utilize the feedback function, specifically the ReadBack facility, on the Output function block **160**. In other words, the field device **38** may be able to communicate the presence of the undesired condition using the existing function blocks without additional bandwidth.

[0044] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

1. A system comprising:

an industrial controller configured to control a first field device;

the first field device comprising:

an actuator;

a positioner coupled to the actuator and configured to position the actuator, wherein the first field device is configured to detect an undesired condition and to communicate the undesired condition to the industrial controller by using a ReadBack facility of the first field device.

2. The system of claim **1**, wherein the first field device comprises a Foundation Fieldbus first field device configured to communicate with the industrial controller.

3. The system of claim **2**, wherein the Fieldbus Foundation first field device comprises a Foundation Fieldbus digital output (DO) function block, a Foundation Fieldbus analog output (AO), or a combination thereof, having the ReadBack facility.

4. The system of claim **3**, wherein the ReadBack facility comprises a Fault State Active sub-status code/category configured to indicate the undesired condition.

5. The system of claim **4**, wherein the Fault State Active sub-status code/category is configured to be transmitted by publish/subscribe protocol from the BKCAL_OUT parameter of the Foundation Fieldbus digital output (DO) function block, the Foundation Fieldbus analog output (AO), or a combination thereof.

6. The system of claim **3**, wherein the first field device is configured to set the Foundation Fieldbus digital output (DO) function block, the Foundation Fieldbus analog output (AO), or a combination thereof to a Manual, Out of Service, or Local Override mode.

7. The system of claim **1**, wherein the first field device comprises a valve having an inlet and an outlet, and wherein the actuator is configured to enable a flow between the inlet and the outlet.

8. The system of claim **1**, wherein the positioner comprises a linear positioner configured to transform linear motion into an actuator position, a rotary positioner configured to transform rotary motion into the actuator position, or a combination thereof.

9. The system of claim **1**, wherein the industrial controller is configured to control a second field device based on the undesired condition, and the second field device is configured to provide redundant operations for the first field device.

10. The system of claim **1**, comprising a commissioning system having a placeholder representative of the first field device, wherein the commissioning system is configured to use the placeholder to commission the first field device.

11. The system of claim **1**, wherein the system is an industrial control system comprising a gas turbine system, a gasification system, a steam turbine system, a wind turbine system, a water turbine system, a power generation system, or any combination thereof.

12. A method, comprising:

determining a state of a field device;

deriving a first indication of an undesired condition if the state includes an undesired condition, then;

adding the first indication of the undesired condition to a ReadBack facility; and

communicating the first indication to a control block.

13. The method of claim **12**, wherein communicating the indication comprises using a Foundation Fieldbus communications protocol.

14. The method of claim **13**, comprising placing the field device in Manual, Out of Servicer, or Local Override mode.

15. The method of claim **12**, wherein the ReadBack facility comprises a Fault State Active sub-status code/category configured to include an indication of the undesired condition.

16. The method of claim **12**, comprising:

deriving a second indication of a recovered condition if the state includes a recovered condition, then;

adding the second indication of the recovered condition to the ReadBack facility; and

communicating the second indication to a control block.

17. The method of claim **12**, wherein the field device is included in an industrial control system comprising a gas turbine system, a gasification system, a steam turbine system, a wind turbine system, a water turbine system, a power generation system, or any combination thereof.

18. A non-transitory tangible computer-readable medium storing a plurality of instructions executable by a processor of an electronic device, the instructions comprising:

instructions to determine a state of a field device;

instructions to derive an indication of an undesired condition if the state includes an undesired condition, then;

instructions to add the indication of the undesired condition to a ReadBack facility; and

instructions to communicate the indication to a control block.

19. The medium of claim **18**, wherein communicating the indication comprises using a Foundation Fieldbus communications protocol.

20. The medium of claim **18**, wherein the ReadBack facility comprises a Fault State Active sub-status code/category configured to include an indication of the undesired condition.

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